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BULLETIN

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OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAM FOR THE

NEW YORK MEETING

FEBRUARY 25-26, 1927

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

AT COLUMBIA UNIVERSITY

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
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The American Physical Society

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BULLETIN

of the

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FEBRUARY 12, 1927 Vol. II, No. 1

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

NEW YORK MEETING, FEBRUARY 25–26, 1927

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

The 143rd regular meeting of the American Physical Society will be held in New York City at Columbia University on February 25–26, 1927, as a joint meeting with the Optical Society of America. All sessions will be held in the new Physics Laboratories on 120th Street, east of Broadway. (Entrance at 119th Street and Broadway.)

Optical Society. The sessions of the Optical Society will be held on Friday morning and afternoon in Room 428. The morning sessions will begin at 9:30 o'clock. The program of the afternoon session, beginning at 2:15 o'clock will consist of two invited papers by PROFESSOR F. K. RICHTMYER of Cornell University on "The Extension of the Classical Laws of Optics into the X-Ray Region of the Spectrum," and by PROFESSOR R. W. WOOD of Johns Hopkins University on "The Experimental Control of the Radiating States of Optically Excited Atoms."

American Physical Society. The sessions of the Physical Society will be held on Saturday morning and afternoon in Rooms 401 and 428. The morning session will begin at 10:00 o'clock. Both sessions will be divided into two sections.

Inspection of the new Physics Laboratories. The new Physics Laboratories of the University will be open for inspection all day on both Friday and Saturday.

Luncheon. A complimentary luncheon will be served on Saturday from 12:30 to 1:30 P.M. on the 12th floor.

Titles and abstracts of papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts of the Physical Society papers will be published in the Physical Review, and of the Optical Society papers in the Journal of the Optical Society of America. Authors should send corrections to the editors of the respective journals.

HAROLD W. WEBB, *Secretary,*
Columbia University, New York, N. Y.

February 12, 1927.

CALENDAR

Sessions of the Optical Society of America:

Friday morning:	9:30 o'clock	Room 428	Papers 1–12
Friday afternoon:	2:15 o'clock	Room 428	Invited papers by PROFESSOR F. K. RICHTMYER and PROFESSOR R. W. WOOD

Sessions of the American Physical Society:

Saturday morning:	10 o'clock	Room 401	Papers 1–11
		Room 428	Papers 12–23
Saturday afternoon:	2 o'clock	Room 401	Papers 24–35
		Room 428	Papers 36–45

The supplementary paper No. 46 may be called for at the end of any session of the Physical Society in Room 401.

Other meetings of the Physical Society during the current season are as follows:

144. March 5, 1927. Pacific Coast Section at Los Angeles.
145. April 22–23, 1927. Washington.
146. June 22–25, 1927. Pacific Coast Section at Reno, Nevada.
147. November 25–26, 1927. Chicago.
148. December 27–30, 1927. Nashville, Tenn. Annual Meeting.

PROGRAM

FRIDAY MORNING AT 9:30 O'CLOCK

New Physics Laboratories
(Entrance 119th St. & Broadway)
Room 428

Session of

THE OPTICAL SOCIETY OF AMERICA

OFFICERS

President, W. E. FORSYTHE, Nela Park, Cleveland
Vice-President, I. G. PRIEST, Bureau of Standards
Secretary, C. C. BIDWELL, Cornell University
Treasurer, ADOLPH LOMB, Bausch & Lomb Optical Co.
Council: Consists of the above officers, H. E. Ives, P. D. Foote, K. T. Compton, C. E. K. Mees, P. G. Nutting, C. W. Keuffel.

ABSTRACTS OF PAPERS

1. Deane B. Judd — **Munsell Research Laboratory, and Bureau of Standards**

PURITY AND SATURATION; A SATURATION SCALE FOR YELLOW

The relation between purity and saturation, with hue constant, known as a saturation scale, has been evaluated by Nutting and Jones[1] for three hues (red, green, and blue); later by Jones and Lowry[2] for hues corresponding to eight dominant wave lengths; and still later at the Munsell Research Laboratory by unpublished work involving many observers and a number of hues. The results of these investigations are hard to reconcile in all particulars, but they concur in indicating that: (1) the relation, *Purity* = *Constant* × *Saturation*, is approximately correct; and (2) the character of the relationship between purity and saturation is nearly independent of hue.

If we assume that the saturation attached to a visual stimulus by an observer rests upon that observer's color vision and not upon the vagaries of his judgment as determined by education, dyspepsia, etc., the saturation of a visual stimulus may be computed from its dominant wave length and purity, and the relation between purity and saturation is thereby determined. If we take the O. S. A. Excitations as fairly representing average color vision, the following statements are true concerning the relation between purity and a saturation into which cortical or psychological effects are not allowed to enter: (1) Both statements given above and derived from experimental data are correct; (2) for the violet, the deviation of saturation from a straightline relation with purity is very marked; the ratio of the purity increment at purity, 0.9, to the increment at purity, 0.1, is as high as 100.0; (3) and, in general, this ratio is equal to $S(36S+3)/(3S+4)$, where $S = RL_r + GL_g + BL_b$, R, G, and B being the trilinear coördinates of the spectrum, and L_r, L_g, and L_b being the luminosity coefficients attached to the color primaries of the O. S. A. Excitations.

An experimental procedure has been devised whereby the shape of the curve between purity and saturation may be found without the use of liminal determinations. For dominant wave length about 575 mμ, the relation has been determined by two observers. The actual colors corresponding to this saturation scale have been compared by seven other observers

with the colors specified for dominant wave length 575 mμ by the workers above referred to. There has resulted a close check on the non-psychological saturation scale derived from the O. S. A. Excitations, a much closer check, in fact, than that yielded for any of the previously determined experimental scales.

Bibliography:
(1) Nutting, J.O.S.A., *4*, 62 (1920).
(2) Jones and Lowry, J.O.S.A. & R.S.I., *13*, 25, (1926).

The present paper will appear in full in J.O.S.A. & R.S.I. 20 min.

2. Walter H. Stainton **Cornell University**

THE PHENOMENON OF BROCA AND SULZER IN FOVEAL VISION AS DEPENDENT UPON WAVE LENGTH AND INTENSITY

Two luminous fields balanced photometrically will not, in general, appear equal when one of them is exposed for a fraction of a second. By repeated trials, however, the field continuously exposed may be adjusted in brightness to match the apparent luminosity of the flashed field. A series of such matches for various durations of flash has been used by Broca and Sulzer and others to obtain a curve of apparent luminosity as a function of time.

An apparatus has been arranged to use a method essentially that of Broca and Sulzer. A fairly complete set of curves has been obtained for one observer over a wide range of brightnesses.

It is found that the "overshooting" effect appears in the green at brightness levels substantially the same as those for white. The high maxima of Broca and Sulzer for the blue are absent with small fields, as has also been shown by Kleitman and Piéron. At low brightness levels, the maximum is later and less clearly defined than is indicated by the work of Bills. For the light adapted eye, the rate of rise is greater than for dark adaptation at corresponding brightnesses.

Bibliography:
Broca and Sulzer: C.R., 137, p. 944, 977, 1903.
Bills: Psychol. Rev. Monogr., 28, No. 5, 1920.
Kleitman and Piéron: L'Année Psychologique, 25, p. 34, 1924.

The present paper will appear in full in J.O.S.A. & R.S.I. 10 min.

3. Theodore Lyman **Harvard University**

THE GAP IN THE SPECTRUM

The paper contains a review of the recent attempts to investigate the radiations lying in the region between soft x-rays, λ20, and the extremest ultraviolet, λ200.

It is pointed out that the indirect method in which the photoelectric action of soft x-rays is employed yields results which cannot be easily interpreted in this region. Papers of O. W. Richardson[1] and K. T. Compton[2] are cited in this connection.

The investigations of Thibaud[3] with a glass grating and of Dauvillier[4] with a crystal lattice are discussed in the light of some recent work of the author.

Bibliography:
1. O. W. Richardson, Proc. Roy. Soc. Vol. 110, p. 247, 1926.
2. K. T. Compton, Physical Rev., Vol. 28, p. 601, 1926.
3. Jean Thibaud, C. R., Vol. 182, p. 1141.
4. A. Dauvillier, Nature, Oct. 16, p. 551, 1926. 20 min.

4. N. Rashevsky **Research Dept., Westinghouse Electric and Manufacturing Co.**

LIGHT-QUANTA AND MAXWELLS EQUATIONS

In a recent paper[1] N. Kasterin attempted to show, that the model of a light-quantum, proposed by Sir J. J. Thomson, namely that of a closed tube of force moving with the velocity of light[2] may be obtained as a solution of Maxwells Equations, provided we admit also discontinuous solutions.

In the present paper it is pointed out that any discontinuity of the field behaves *formally* either like a charge or a current. And since we can observe and measure charges and currents

only by their action, that is, by their *behaviour*, the assumption of discontinuities of the field, necessary to give a picture of J. J. Thomson light-quantum, leads to the conclusion that such a light-quantum carries not only energy, but also charge, or, if it is electrically neutral, a system of currents, suitably distributed. In other words, we must ascribe to the quantum a complicated internal structure, which conclusion is not exempt of certain difficulties.

A further investigation shows, however, that although the solution, proposed by N. Kasterin cannot be regarded as quite satisfactory, there is still no reason to believe in a necessary contradiction between the conception of directed quanta and Maxwells Equations. Even considering only such solutions which are represented by retarded potentials, we obtain radiation in spherical waves only when certain restricting conditions are implied. It is shown that in a general case the possibility of a directed radiation is not excluded also for these solutions.

Bibliography:
1. Phil. Mag. [7] II, p. 1208, 1926.
2. Ibid. [6] XLVIII, p. 737, 1924 and 1, p. 1182, 1925.

15 min.

5. Ludwik Silberstein and Clifton Tuttle **Research Laboratory, Eastman Kodak Co.**

THE RELATION BETWEEN THE SPECULAR AND THE DIFFUSE PHOTOGRAPHIC DENSITIES

The purpose of the paper is to derive theoretically a formula correlating the so-called specular and diffuse density of a layer of a light-scattering medium, such as a developed photographic film or plate, and to test it experimentally. In accordance with the actual method of measurement of the two kinds of "density," the specular density (D) is defined as the common logarithm of the ratio of the intensity of the incident light to that of the beam transmitted normally to the layer, which will include some fraction (ϵI_s) of the scattered light, and the diffuse density (D') as the logarithm of the ratio of the intensities of the incident and the total transmitted light including the whole scattered light. The incident rays are in both cases supposed to be collimated normally to the layer.

It is assumed that of the direct (collimated) light, of intensity I, penetrating to any depth each silver grain scatters the amount AI and absorbs $\kappa\omega I$, where ω is the average effective area of a grain, κ a numerical factor, and A a coefficient depending on the wave length and the size of the grain. Also part of the scattered light (I_s) produced within the layer is absorbed by the grains, and as these show no trace of orientation, the amount absorbed by a grain is again expressed by $\kappa\omega I_s$, i.e., with the same coefficient as for the direct light. The effect of an "infinitesimal" stratum with regard to both scattering and absorption is taken to be proportional to the number of grains contained in it. Under these circumstances the finally emerging intensities I and I_s are found at once by solving a pair of simple differential equations. Whence follow the densities $D=\text{Log}\,[I_o/(I+\epsilon I_s)]$ and $D'=\text{Log}\,[I_o/(I+I_s)]$ as functions of the total number (n) of grains per unit area of the layer. Eliminating n, the required relation between the two densities is found to be

$$10^{-D}=\epsilon\cdot 10^{-D'}+(1-\epsilon)\cdot 10^{-\beta D'},$$

where $\beta=1+A/\kappa\omega$ and the significance of the fraction ϵ is as above. Equivalently, in terms of transparencies,

$$T=\epsilon T'+(1-\epsilon)T'^{\beta}$$

A devise for determining the constants ϵ, β from two observed pairs of corresponding D, D' being given, the formula is tested on the experimental results obtained with five different kinds of emulsion representative of various grain sizes, and is found to give in each case a close agreement.

The present paper will appear in full in J.O.S.A. & R.S.I.

15 min.

6. Thornton C. Fry **Bell Telephone Laboratories, Inc., New York City**
Introduced by H. E. Ives

LIGHT WAVES IN METALS

When a wave of plane polarized light falls obliquely upon a conducting surface, it gives rise to a disturbance inside the conductor which has, among others, the following peculiarities:

(a) It is neither plane nor elliptically polarized, but belongs to a third distinct category; (b) it does not travel with what is customarily called "the speed of light"; (c) its velocity varies with the angle of incidence.

There are similar light waves in dielectrics and in free space.

15 min.

7. Lauriston Taylor — **Cornell University**

A Comparison of Three Methods of Spectrophotometry of Weak Light

A comparison of sensitivity and precision was made for the three spectrophotometric methods employing the following instruments: (1) Lummer-Brodhun spectrophotometer, (2) a spectrograph in which the comparison spectra were photographed simultaneously by means of a divided slit, (3) a photoelectric spectrophotometer. The comparisons were made for intensities of light near and below the lower limit of visual observation. In the photographic method, several different plates were used. The last method employed a photo-electric cell in place of the eye and was used with a large aperture spectrometer. A high sensitivity Compton electrometer was used to measure the photo-electric current. For light that could be seen only after dark adaptation, the error of observation by method (1) was of the order of 16 per cent. With 1/200 of the above intensity the error by method (2) was 5 per cent to 25 per cent depending upon the plate used and the time of exposure. This method required exposures from 2-20 hours in length for a single comparison. For the same intensity (1/200) of light, the error by the photoelectric method was 2 per cent to 6 per cent, and the time required for an obseration was about 5 minutes or less. The time required for a set of six observations with corresponding dark drifts was about 30 minutes. The chief factors which govern the precision and sensitivity of this method are: the type and sensitivity of the electrometer and the potential applied to the cell. There is a considerable gain in precision at the expense of sensitivity.

The present paper will appear in full in J.O.S.A. & R.S.I.

12 min.

8. C. W. Woodworth — **University of California**

The Wave Front in the Focus of a Corrected Lens

A new method for calculating the optical length of a ray of light passing through a lens is presented together with examples of the calculation of a series of rays through the great 36-inch telescope objective at Lick Observatory.

The purpose of these calculations is to determine with extreme accuracy the character of the wave front in the focus of a highly corrected lens. It is well known that in an uncorrected lens the wave front passes through a very complicated transformation (Microscope Theory, pp. 56–59) and because of the unavoidable zonal aberrations one could assume that there were comparable transformations in the focus of a corrected lens which proves to be true.

This is an important matter in the theory of diffraction where one considers differences of half wave lengths. It has been previously assumed in the discussion of diffraction that the wave front approached the focus as a spherical surface.

Bibliography:

Woodworth, C. W., Microscope Theory, Trans. Science Soc. of China, 1924, pp. 29–230.

The present paper will appear in full in J.O.S.A. & R.S.I.

15 min.

9. Christine Ladd-Franklin — **Columbia University**

Proof That Nerve When Excited, and Probably Also When not Excited, Emits Physical Light

There is an entoptic phenomenon—what I have called the *Reddish-Blue Arcs and the Reddish-Blue Glow of the Retina*—in which it is easily shown that what you are seeing is

certain excited nerve fibers which proceed on the surface of the retina to the exit point of the optic nerve (the papilla). But why is an excited nerve fiber visible? The theory that has been given of this phenomenon (by Gertz and others) is that an excited nerve fiber will produce an induced electric current in adjoining fibers, and through them make itself visible. But it is plain that such a nerve excitation as this would not reach the cortex with the required "place-coefficients,"—when a leg has been amputated, pinching the cut nerve fibers does not give a sensation located at the place where they are pinched but at the toes or the heel. Nothing but light will cause an object to be seen at the place where it is. It follows that in this case the excited nerve fiber is actually emitting physical light. But absolute proof of this view is furnished by the fact that these reddish-blue arcs give an after-image, and that after-images do not occur in the case when a nerve only is excited:[1] the highly specific form of exhaustion that takes place in the light-sensitive substance of the rods and cones is essential to the production of the after-image.[2]

But if all nerve when in a state of activity emits physical light (or some radiation of higher frequency which immediately becomes physical light through fluorescence), why has this not been discovered long since? There are two reasons for this: most work on nerves is done on myelinated nerves—those in the retina are non-myelinated and consequently let light through; one does not usually study the nerve in a perfectly dark room—what is necessary to seeing this reddish-blue light.

Shiro Tashiro and G. H. Parker have shown that carbon dioxide is given off even by unexcited nerve. Hence light also may be emitted by unexcited nerve.

Bibliography:

1. Lasareff, P., Comptes rendus, 1924, *178*, p. 1100.
2. Nodon, A., Comptes rendus, 1924, *178*, 486.

The present paper will appear in full in—Psyche. 15 min.

10. Henry J. Miller **Research Laboratory, General Elec. Co., Nela Park**

ABSORPTION SPECTRA OF SOME ORGANIC DYESTUFFS AND THE USE OF THESE DYESTUFFS FOR "MONOCHROMATIC" LIGHT-FILTERS IN THE ULTRAVIOLET PART OF THE SPECTRUM

The absorption spectra of the following dyestuffs were investigated:

1. p-Nitroso-ethyl-aniline (Merck)
2. p-Nitroso-diethyl-aniline (M)
3. 5-Diethylamino-2-nitrose-phenol (Kahlbaum)
4. p-Nitroso-ethyl-aniline hydrochloride (Kahlbaum)
5. p-Nitroso-diphenylamine (Kahlbaum)
6. p-Nitroso-methyl-aniline (M)
7. p-Nitroso-dimethyl-aniline (By)
8. p-Nitroso-dimethyl-aniline (Merck)
9. Fuchsine (blaust, M)
10. Uranine
11. Diamond fuchsine (by)
12. China green (By)

These dystuffs were diluted in water and ethyl alcohol and the absorption spectra were observed as a function of degree of dilution. It was found that, for example, p-Nitroso-dimethyl-aniline (By) and Fuchsine (blaust, M) have two absorption bands, which are covering the entire spectrum of the mercury vapor arc, when the two solutions are combined to a double filter, transmitting only the ultraviolet lines from 3900 Å to 2950 Å. Therefore a suitable filter transmitting only ultraviolet radiation can be made out of these dyestuffs. The same principle for obtaining suitable "monochromatic" light filters can be applied for numerous other dyestuffs and for all parts of the light spectrum.

Bibliography:

1. W. N. Hartley, Relations between absorption and constitution of organic compounds in H. Kayser, Handbuch der Spectroscopie, Vol. III, 1905.
2. Jaroslav Formanek, Untersuchung und Nachweis organischer Farbstoffe auf spectroscopischem Wege, Berlin 1908–1926.

10 min.

11. Deane B. Judd **Munsell Research Laboratory, and Bureau of Standards**

THE EMPIRIC RELATION BETWEEN DOMINANT WAVELENGTH AND PURITY

It has long been known that the same hue might not be attached to two visual stimuli of the same dominant wavelength but of different purities. Although Abney[1] made quantitative measurements of the "hue shift," his results are rendered somewhat uncertain by doubt as to the true "neutrality" of his standard "white."

Observations incidental to a protracted series of color analyses by the monochromatic method have resulted in a qualitative check of Abney's findings, and with a standard "neutral" that is completely specified. The observations which refer to dominant wavelengths greater than 500mμ have been accounted for on the basis of the well-known saturation changes with wavelength at constant purity, as follows:

(1) For dominant wavelengths between 500 mμ and 570 mμ, a decrease in the purity of the test field results in a lower experimental dominant wavelength for the sample.

(2) For dominant wavelengths between 570 mμ and 640 mμ, a decrease in the purity of the test field results in a higher experimental dominant wavelength for the sample.

In these cases, the range of possible values for dominant wavelength of the sample is largest for those wavelength regions in which sensibility to wavelength change is smallest, and the direction of the variation of dominant wavelength with purity is such that two fields of slightly different hue are reacted to as matched because the saturations they evoke are equal, the hue difference being too slight to be perceived.

If the dominant wavelength of the sample is less than 460 mμ, a reduction of the purity of the comparison field makes the field appear more violet than before and leads to an increase in the experimentally determined dominant wavelength of the sample. A change toward this higher wavelength does not tend, however, to equate the saturations of the two fields; hence the explanation which holds for the long wavelengths fails for the short. No simple alternative explanation seems to exist.

Bibliography:

(1) Abney, On the Change of Hue of Spectrum Colors by Dilution with White Light, Proc. Roy. Soc., A., *87*, (1909).

The present paper will appear in full in J.O.S.A. & R.S.I. 10 min.

12. P. V. Wells and O. E. Conklin **Redpath Laboratory, Dupont-Pathe Film Mfg. Co., Parlin, N. J.**

THE MENTAL FACTOR IN VISUAL ACUITY

In testing the visual acuity of applicants for the plant, the measurements revealed, in addition to the retinal acuity, a mental factor. This factor could not be eliminated from the criterion of acuity, indeed it appears to be an attribute essential to all measures of sensations. The paper describes a method for determining visual acuity which is free from subjective bias, and presents results which show the importance of the mental factor.

Black broken circles of geometrically graded size on white paper are successively placed before the subject for three seconds at a time. The break may be in one of four positions, top, left, right or bottom. The answers are corrected for the fact that one quarter of the positions can be guessed correctly. The acuity criterion is the least angular opening resolved in one half the trials. Long after the subject has become fully accommodated to the low level of illumination (safe for cine-negative for 30 minutes), and in spite of frequent rest periods, the acuity can apparently double because of mental changes in the observer. Extreme caution, therefore, must be exercised not to grade operators falsely because of accommodation, fatigue, and psychological disturbing factors.

The present paper will appear in full in J.O.S.A. & R.S.I. 10 min.

FRIDAY AFTERNOON AT 2:15 O'CLOCK

Session of the Optical Society
Room 428

The program on Friday afternoon will consist of two invited papers as follows:

PROFESSOR F. K. RICHTMYER — Cornell University
"The Extension of the Classical Laws of Optics into the X-Ray Region of the Spectrum."

PROFESSOR R. W. WOOD — Johns Hopkins University
"The Experimental Control of the Radiating States of Optically Excited Atoms."

SATURDAY MORNING AT 10 O'CLOCK

Session of the Physical Society
Room 401

1. A system of structures for atomic nuclei. WARREN W. NICHOLAS, National Research Fellow, Cornell University.—First, a neutron structure is assumed (proton inside electron) which may offer a simple basis for the "packing effect." Second, the known series of isotopes is discussed with reference to the postulate that evolution of light elements was from complex to simple, the nuclei losing units smaller than the α-particle. Third, a geometrical structure for the atomic nucleus (protons and neutrons on alternate cube corners in a cubic lattice) is assumed which shows some main features in common with the known nuclear series. Fourth, a specific structure is proposed for the nucleus of Sulphur 32 which can be followed through consecutive disintegrations, thereby accounting for the known isotopes from Sulphur 32 to Helium 4. Several of the disintegrations seem rather arbitrary, but some of the results, especially concerning the symmetry of the abundant nuclei, are suggestive. The above theory may be tested by (1) further experiments on artificial disintegration, and by (2) precision determination of isotope masses.

2. Theory of the magnetic nature of gravity and the Balmer series. CORNELIO L. SAGUI, Castelnuovo dei Sabbioni, Italy.—In a preceding paper dealing with a corpuscular conception of energy the equation $(x^2+x)/2=y$ was found for the variation of the gravitational potential of physical nature, at least for an atomic space. The geometrical variation due to the Newtonian law is here not considered. With the same equation the Balmer lines are now studied and a physical meaning found for doublets, triplets and other groups of this kind. The Stark effect is also considered. The radiation of energy is also investigated and it is supposed to be due to a magnetic depression on the front of the traveling ray. Suggestion is given as to the astronomical verification of such a fact.

3. The potential of photoactive cells containing fluorescent electrolytes. H. W. RUSSELL, Cornell University.—The variation of the potential of a photoactive cell containing a fluorescent electrolyte with time of illumination has long been a subject of dispute. Goldmann in particular, having noted that the potential approached a maximum which was independent of the intensity of the exciting light, arrived at a potential-time law on a theory involving the Hallwachs photo-electric effect. Measurements on cells with sputtered platinum electrodes containing Rhodamin B in absolute alcohol have been made. The potential has been measured with a string electrometer

of small capacity and short period. Goldmann's limiting potential was not found. The magnitude of the effect does not vary with the frequency of the exciting light in accord with the true photo-electric effect, yellow light being more effective than blue light of the same intensity. A theory has been developed on the assumption that the exciting light causes a permanent chemical change in the electrolyte. Diffusion plays an important part in the potential-time relation. This theory predicts the shape of the potential-time curve and its variation with the intensity of the exciting light.

4. Optical absorption and photo-electric conductivity of sulphur crystals. B. KURRELMEYER, Harvard University.—The optical absorption and photo-electric conductivity of single crystals of rhombic sulphur have been measured over the visible spectrum. The absorption is complete in the violet, but is relatively low from 500 to 650 mμ. The photo-electric conductivity is measurable between 400 and 650 mμ; its maximum, referred to unit incident energy, lies at 470 mμ. There is strict proportionality between photocurrent and light intensity and between photocurrent and electric intensity throughout the ranges used. If there is a saturation value of the electric intensity it probably lies above 30,000 volts per cm, and is therefore very much higher than the saturation electric intensity in the diamond and in zincblende. This fact may be connected with the relative magnitudes of the refractive indices. The conductivity referred to unit absorbed light energy does not seem to obey the linear relation demanded by the quantum mechanism usually assumed for its production.

5. The periodicity of photo-electric thresholds. GEORGE B. WELCH, Cornell University.—Considering the photo-electric threshold as a measure of the energy taken from the incident radiation in order to detach one of the outer electrons from its atom, the elements having the most loosely bound electrons should permit detachment with the expenditure of minimum amounts of energy. Using the present available data, the curve showing the relation between photo-electric thresholds and atomic numbers exhibits a certain periodicity with strong maxima for the alkali metals and decreasing values as one proceeds towards the more electronegative elements. The curve also shows minor peaks for Cu and Ag, but none for Au, where it might have been expected. When the widely varying conditions of observation are considered the amount of agreement is surprisingly good. A new measurement for the threshold of Ge (2590 A) and a tentative one for Be are included; both of these assume their expected positions on the curve.

6. On the condition of validity of macromechanics. M. S. VALLARTA, Massachusetts Institute of Technology.—The problem considered in this paper is: Assuming the associated wave of De Brogile and Schrödinger, under what conditions do the trajectories orthogonal to the equiphase surfaces of the wave (i. e., the rays) coincide with the mechanical paths determined by the classical Hamilton principle? If $\alpha(xyz)$ is the amplitude of the associated wave, sufficient conditions are shown to be: (a) α satisfies Laplace's equation, i. e. there are no discontinuities in the "medium" where the wave propagates; (b) the frequency of the associated wave is infinite, i. e. Planck's constant vanishes. The necessary and sufficient condition is that the equiphase surfaces determined from the wave equation coincide with the (classical) surfaces of constant action. De Broglie's condition for the validity of macromechanics (Journal de Physique, **7**, 321, (1926)) is then examined the applications to the hydrogen atom are given. The Sommerfeld-Wilson quantum conditions and their generalization by Wentzel (Zs. für Physik, **38**, 518, (1926)) are studied in the light of the above criteria, and it is shown that an azimuthal quantum condition always has a meaning, not however a radial quantum condition.

7. An analysis of the arc and spark spectra of scandium. HENRY NORRIS RUSSELL, Princeton University, and WALTER F. MEGGERS, Bureau of Standards.—New measures of the arc spectrum (in which practically all the enhanced lines appear) have led to the classification of 337 lines of Sc I and 131 of Sc II leaving only a few weak lines out-

standing. The spark spectrum is relatively simple. The lowest terms are ^3D, ^1D, arising from the electron configuration $3d \cdot 4s$. Next come $^3F'$, $^3P'$, ^1S, ^1D, ^1G from $3d \cdot 3d$. All these terms combine with ^3P, $^3D'$, ^3F, ^1P, $^1D'$, ^1F from $3d \cdot 4p$; and these again with ^3S, $^3P'$, ^3D, $^3F'$, ^3G, $^1P'$, ^1D, from $3d \cdot 4d$, and ^3D, ^1D from $3d \cdot 5s$. The last are in series with the lowest terms, and indicate an ionization potential of 12.8 volts. A ^3P term arising from $4s \cdot 4p$ and a $^3P'$ from $4p \cdot 4p$ are also present. The arc spectrum is much more complex. The lowest term is $^2D(3d \cdot 4s \cdot 4s)$; then $^4F'$, $^2F'$, ^2D, ^2G, ^4P $(3d \cdot 3d \cdot 4s)$. The configurations $3d \cdot 4s \cdot 4p$ and $3d \cdot 3d \cdot 4p$ give numerous "middle" terms combining with these. Higher terms have been identified as arising from $3d \cdot 4s \cdot 5s$; $3d \cdot 3d \cdot 5s$; $3d \cdot 3d \cdot 3d$; $3d \cdot 4s \cdot 4d$, and $3d \cdot 4p \cdot 4p$. The first two of these belong to series and give the ionization potential 6.7 volts for the neutral atom. There are strong intercombinations between the doublets and quartets in the red, and weak ones in the ultra-violet. All details of the structure of both arc and spark spectra are in complete agreement with Hund's theory.

8. Multiplets in the spectra of vanadium (III). R. C. GIBBS and H. E. WHITE, Cornell University.—Using the regular and irregular doublet rules as guides, it has been found possible, from the corresponding known multiplets in Sc_I and Ti_{II}, to identify the triad of multiplets of V_{III} designated as $^4F_{2,3,4,5} - {}^4G_{3,4,5,6}$; $^4F_{2,3,4,5} - {}^4F'_{2,3,4,5}$; and $^4F_{2,3\,4,5} - {}^4D_{1,2,3,4}$. For these multiplets the initial state is given by one $4p$ electron and two $3d$ electrons. In the final state the $4p$ electron has shifted to a $4s$ orbit. The separations of the $^4F_{2,3,4,5}$ levels are found to be in the ratio 2.50 :3.52 :4.50, in very close agreement with Lande's interval rule which for these levels gives 2.5 :3.5 :4.5. The relative intensities of the lines in these multiplets conform to the usual rule. A comparison of the data for one, two, and three electron systems of Sc, Ti, and V shows that the addition of first one and then a second d electron causes not only an increase in the multiplicity but also successive shifts in the radiated lines toward the longer wave-lengths by very nearly the same frequency interval. It has also been found possible to identify the $^4F_{2,3,4,5} - {}^4F'_{2,3,4,5}$ multiplet of Cr_{IV}.

9. A quantitative test of Hund's theory of doublet bands of the OH type. E. C. KEMBLE and F. A. JENKINS, Harvard University.—According to Hund (Zeits. f. Phys. **36,** 657, (1926)) multiple electronic levels in molecules are due to different orientations of the electron spin vector relative to the internuclear axis. At low nuclear speeds the component of the spin vector parallel to the nuclear axis is quantized while at high speeds the component parallel to the resultant angular momentum is quantized. The consequent distortion of the molecule gives rise to bands in which each branch is composed of doublets or triplets with a maximum separation at the origin. In the case of doublets the effect of the distortion on the rotational term formula has been carried through quantitatively by one of the authors (Kemble) and the resulting equations have been tested on the data for NO beta bands by the other (Jenkins). The two levels involved have equal moments of inertia but different values of B in the empirical formula $E/h = A + Bj^2 + Cj^3 + \cdots$ The observations confirm the theory and in particular check the following formula for $B{:}B = (1 \pm z)^2 h/8\pi^2 I \pm z^2 \Delta_0$ where Δ_0 = term difference for doublet at zero rotation and $z = h/(8\pi^2 I \Delta_0 - 2h \pm 2h)$. The upper sign in each case goes with the lower level of the pair

10. Vibrational levels in the blue-green band system of sodium. F. W. LOOMIS, New York University.—The lines in Wood's magnetic rotation spectrum of sodium vapor may, according to Kemble's theory of the Zeeman effect in band spectra, be considered as approximately representing band origins. Most of those in the blue-green region have been arranged into a band system and their frequencies formulated, in terms of the (integral) vibrational quantum numbers n' and n'', which can, by comparison with the fluorescent series, be unambiguously assigned, as follows:

$$\nu = 20301.7 + (124.13n' - 0.84n'^2) - (158.5n'' - 0.73n''^2 - 0.0027n''^3).$$

The location of the n'' levels makes it possible to plot the fluorescent series in the manner used with iodine and to identify approximately the bands to which the fluorescent lines belong. Moreover, when n' and n'' are plotted for all the rotation lines identified, a wide open parabola-like figure appears, of a type which Condon (Phys. Rev. **28,** 1182 (1926)) has accounted for in terms of an hypothesis of Franck. This explains the effect on the fluorescent spectrum of varying the frequency of the exciting light, as reported by Wood (e. g. Physical Optics, Frontispiece, Fig. 8); since the separate patches in the blue and yellow which result from stimulation with blue light correspond to the two arms of the parabola, and the single green patch due to green stimulation corresponds to the vertex.

11. Note on "pendulum" orbits in atomic models. R. B. LINDSAY, Yale University.—"Pendulum" or straight line orbits in an atom are usually ruled out as physically impossible since they apparently involve collision of the electron with the nucleus. Nevertheless their value in fixing energy levels was suggested a few years ago by J. W. Nicholson, who sought to show that in the simple two body problem such orbits are possible with quantized energy values of the same form as those of the circular and elliptic orbits (viz., $W = -2\pi^2 Ne^4 m_0/n^2h^2$). Unfortunately in his relativity analysis he used the rest mass m_0 throughout instead of the varying mass m. Correction of this error shows that his result is invalid without some modification of his premises. The present writer has been able to obtain quantized "pendulum" orbits with energies equal to the Balmer terms by the assumption that in addition to the inverse square force of attraction between nucleus and electron there is an inverse cube (or higher power) force of repulsion of such a character that it is effective only in the close vicinity of the nucleus, i. e. at a distance of the order of magnitude of 10^{-12} to 10^{-13} cm. It is believed that the result may be of interest in view of the possible utility of straight line orbits in atomic models with more than one electron.

SATURDAY MORNING AT 10 O'CLOCK

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12. Magnetic moments of iron in complex salts. L. A. WELO and O. BAUDISCH, Rockefeller Institute for Medical Research.—Although the moment of iron is 29 magnetons (Weiss) in the ferric ion and about 26 in the ferrous ion, it is known that the moment is nearly zero in the ferrocyanides, the pentacarbonyl and the nitroprusside and that it is about 10 magnetons in the ferricyanides. The moment in the ferricyanides is probably the same as in the divalent copper ion. Possibly still other moments in iron may be found, and these may correspond to the ions of other transition elements. With this in view we have made a preliminary survey of 45 rare salts obtained from Professor Weinland of Würzburg. Twenty eight salts have the normal moment of simple ferric salts. Seven are hex-acetates of the type $[Fe_3(CH_3COO)_6\ (OH_2)]$ Cl and form a well defined group in which each iron atom has the same moment as the nickel ion with 16 magnetons. A hexa-benzoate $[Fe_3(C_6H_5COO)_6\ (OH)]\ ClO_4 \cdot C_6H_5COO$ also falls within this group corresponding to nickel. Two complex glycolates $(CH_2O \cdot COO)$ apparently correspond to the chromium ion with 19 magnetons. No correspondences are noted in remaining salts. It was assumed that the salts obey the simple Curie law. Experiments to test this question are under way.

13. Velocity selector for atomic rays. J. TYKOCINSKI-TYKOCINER, University of Illinois.—An atomic ray on its way towards a target is directed through two vibrating slits suspended in a magnetic field at a distance D apart. The vibrations are controlled by a piezoelectric oscillator. The emerging ray contains selected velocities. For small

ratios of the width w of the slits to its amplitude a, the selected velocities are determined by $v_n = 2Df/n$, where f is the frequency of the vibration and $n = 0, 1, 2, 3$, etc. For larger w/a ratios velocity bands may be obtained each embracing a range

$$v_n' - v_n'' = 2Df[1/(n - w/2\pi a) - 1/(n + w/2\pi a)]$$

When used in connection with Gerlach and Stern magnetic moment analyzer, spectrum-like images should be obtained consisting of n pairs of sharply defined lines each showing a deflection

$$S_n = [(M^2n^2/8mD^2f^2)\ (\partial H/\partial S)_0]\ [\tfrac{1}{2} + \{1/12 + (\partial H/\partial S)_a/\tfrac{1}{8}(\partial H/\partial S)_0\}^{1/2}]$$

$$d_n = (\delta H/\delta S)\ (\tfrac{1}{2} + K)M^2nw/4mD^2f^2\pi a$$

The value for the magnetic moment M may be determined from either of these relations. For a selector, which is in the course of construction, the following data have been computed for rays of atomic hydrogen at 500°K ($f = 9000$ and $n = 2$): $v_n = 1800$ m/sec; $S_n = 1.5$ mm and $d_n = 0.095$ mm.

14. A general proof of the Langevin-Debye formula and the susceptibilities of O_2 and NO. J. H. VAN VLECK, University of Minnesota.—Using the new quantum mechanics, the formula $\alpha + N\mu^2/3kT$ given by Langevin and Debye for magnetic and dielectric susceptibilities respectively is derived without specializing the model further than to assume that the precession frequencies of the moment vector are small compared to kT/h. These precessions may be due to temperature rotation, coupling of spin magnetic moment relative to axis of figure, etc. Thus the Debye formula for dielectric constants is applicable even to asymmetrical polyatomic molecules. Previous explanations of the paramagnetic susceptibilities of gaseous molecules involved the unreasonable assumption of a magnetic moment freely quantized relative to the magnetic field, but now it can be quantized either with reference to the figure or temperature rotation axis (Hund's couplings of types a and b). Quantitative results agreeing with experiment to within about 1% are obtained assuming ^3S normal levels in O_2, and Mulliken's suggestion of ^1P states separated by 122 cm^{-1} in NO. In NO the calculations include corrections for the fact that the contribution of the spin moment is somewhat diminished by its precession frequency (122 cm^{-1}) being comparable to kT/h, while the orbital moment precesses so fast that only its axial component $\sigma = 1$ is effective.

15. The intensity of scattered x-rays and the Compton effect. G. E. M. JAUNCEY, Washington University.—Williams (Phil. Mag. **2**, 657, (1926)) and Jauncey (Phys. Rev., **29**, 206, (1927)) have shown that the experimental intensity of x-rays reflected by crystals can only be calculated on theoretical grounds on the assumption that it is only the electrons in the U state (Phys. Rev., **27**, 687, (1926)) which take part in the Bragg reflection. In the present paper it is assumed that all the electrons in the U state in a given atom cooperate in the unmodified scattering. This requires that the unmodified scattering per atom varies as F^2 and the modified scattering as $(Z - F)$, where F is the atomic structure factor as calculated by Williams and Jauncey and Z is the atomic number. The ratio of the scattering in a given direction to the Thomson scattering in the same direction is then approximately (so long as $F > 1$) given by $(F^2 + Z - F)/Z$. Calculated and experimental values, the latter in parentheses, follow for $\lambda = 0.41$ A scattered by copper: 40°, 4.1 (4.8); 60°, 2.58 (2.5); 80°, 1.88 (2.14); 100°, 1.42 (1.45); 120°, 1.25; 180°, 1.12.

16. The measurement of x-rays used for therapy. HARRY CLARKE, Rockefeller Institute.—If it is desired to measure the dose at a well-defined point, a very small ionization-chamber must be used, and the current will then be so small that it must be measured by means of an electroscope or an electrometer. For accuracy of measurement, as well as for convenience, the meter has to be mounted rigidly at some distance from the tube. On the other hand, the chamber should be movable for convenience in use. The proper design of a conductor to connect the chamber with the meter has, here-

tofore, presented a difficult problem. The conductor must be well-insulated, and protected against both electrostatic induction and leakage due to ionization; it must also be flexible. The writer's apparatus consists of two separate units. The portable unit consists of a small chamber connected with a condenser; the fixed unit is an electroscope with a calibrated variable condenser. The chamber unit is connected with the electroscope for charging; it may then be taken to any part of the laboratory for exposure to the rays. After exposure, it is returned to the electroscope for measurement of the quantity of electricity lost.

17. Reflection of soft x-rays. ELIZABETH R. LAIRD, Mount Holyoke College.—The experiments on the reflection of soft x-rays reported earlier (Phys. Rev. **27**, 510, (1927)) have been repeated for copper, with slight changes in the apparatus, and the results confirmed; showing an absence of regular reflection at angles much above 5° at 950 volts and its presence at 360 volts. Also, at the lower voltage a fraction of the radiation is transmitted through fluorite, and the fluorite fluoresces; at the higher voltage the fluorite is quite opaque and does not fluoresce. It is inferred that the radiation at 950 volts does not include all that present at 360 volts. It is suggested that this may explain the different results obtained by Dauvillier with the crystal reflection method using higher voltages and those of the critical potential method. A glass reflector with partially ground surface was used to show that the ground surface did not reflect.

18. Further test of the theories of absorption of x-rays. F. K. RICHTMYER and L. S. TAYLOR, Cornell University.—At the Philadelphia meeting we reported measurements of the K discontinuity of Ag and Au in an attempt to decide between Kramer's theory of absorption and that of DeBroglie. The uncertainty of the values of the mass scattering coefficients of Ag and Au made it impossible to decide between the two theories. The present measurements on Mo(42), Ag(47) and Sn(50) were made with the hope that the scattering coefficients for these three elements would not be far different and that the two theories might be thus tested. Assuming a reasonable value for σ/ρ, the data for the ratio of K absorption to L absorption are in better agreement with De Broglie's theory. But Kramer's theory gives a better value for the *absolute* magnitude of K absorption at the K limit.

19. The general radiation from a very thin target. WILLIAM DUANE, Harvard University.—Electrons, traveling horizontally with substantially the same velocity, pass through a hole in a block of iron. At its center, they meet the column of mercury moving downward in a mercury vapor pump. The mercury column acts as a very thin target, which continually renews itself. The radiation coming from the impacts of the electrons against the mercury column can be examined through suitable openings. Pin-hole camera photographs taken when the mercury pump is not running indicate some radiation coming from the interior walls of the apparatus. Such photographs taken with the mercury pump running show, in addition to the above, radiation coming from the space in which the electrons hit the mercury column. Measurements by means of an ionization chamber on the absorption of this radiation by aluminium indicate that it is not quite homogeneous, but much more nearly so than the radiation coming from a solid target. The average, or effective wave-length of the radiation is slightly longer than the short wave-length limit of the spectrum calculated from the constant (storage battery) voltage applied. Experiments with x-ray spectrometers on the distribution of energy in the spectrum are in progress.

20. A type of oscillation hysteresis. LAURISTON TAYLOR, Cornell University (Introduced by E. Merritt).—A simple triode oscillator was modified by placing a high resistance (.5–1.0 meg) shunted by a capacity of $1/10\mu f$, in series with the grid. The circuit then oscillates intermittently, the period during which oscillation occurs being called a zule. Over a wide region the zule frequency F is found to obey a simple relation to the

constants of the circuit, i.e., $F = A \exp[(L_2 - kC_2)/2L_1]$, where A and K are constants. At the borders of these regions F is extremely sensitive to very small changes in L_2 and C_2. A theory is given for the zule formation showing how they are related to the state of depression of the grid potential. Their finite length is due to a type of oscillation hysteresis, where oscillation ceases at one value of E_g and is resumed at a higher value. At the end of a zule, the mean of E_g is equal to the dynamic cut-off potential, and at the start of the next zule is several volts higher, increasing exponentially between these values. The variations of E_g were later studied by means of a synchronized oscilloscope, and all points of the theory were checked. Oscillation within the main circuit showed the same formation except that the potential between zules was constant.

21. A shear mode of crystal vibration. W. G. CADY, Wesleyan University.—In the various applications of piezo-electric quartz plates, it has until recently been customary to cut the plates with their faces perpendicular to an electric axis. The vibrations of such plates are then longitudinal, *i.e.*, stationary waves of compression and rarefaction. Various observers have recently found that plates cut *parallel* to the electric and optic axes (*i.e.*, parallel to a natural prismatic face of the crystal; are good piezo-electric oscillators, but hitherto no explanation has been offered. According to Voight's theory of piezo-electricity, an electric field perpendicular to the electric and optic axes causes a shearing stress about the optic axis. Hence the deformation of a plate cut as indicated, when in a field normal to its surface, is a shearing strain, and under an alternating impressed field vibrations are to be expected, whose resonant frequency is determined by the shear-inertia of the plate and by the elastic force of restitution. Computed and observed values of the natural frequency are in satisfactory agreement.

22. Theory and application of low frequency piezo-electric vibrations in quartz plates. J. R. HARRISON, Wesleyan University.—Further study of the phenomena described at the December meeting (Bull. Am. Phys. Soc. **1**, No. 12, paper 12) indicates that the observed frequencies of vibration are sufficiently in accord with those calculated from the formula for flexural vibrations to make it fairly certain that the vibrations are of this type. In general, agreement between theory and observation is best for relatively long plates as would be expected. With relatively long rods the second mode of vibration having three nodes has also been observed. These facts are illustrated by numerical data and curves. An empirical formula has been derived which fits the observed data better than the theoretical equation for flexural vibrations. A plate $30 \times 10 \times 1$ mm vibrating at 60 kc was placed in the circuit of a Type UX-210 tube as a power oscillator. The observed output power was about $\frac{1}{2}$ watt, which considering the low frequency compares favorably with the output from high frequency quartz oscillators.

23. Equations for thermionic emission. W. R. HAM, Pennsylvania State College.—It has recently been shown that an equation of the form $i = A\epsilon^{-bo/T}$ applies as well as any other to experimental data on thermionic and photoelectric emission. The derivation of this equation from Richardson's general equation is now discussed. The value for ϕ assumed is $\phi = \phi_0 - \frac{1}{2}KT - \int_0^x (dv/dx)dx$ where ϕ_0 is independent of T, K is the Boltzmann constant, and dv/dx the potential gradient in the space very near the surface of the thermionic emittor. The experimental and theoretical reasons for the assumption are stated. On substituting this expression for ϕ in the general equation not only the first equation mentioned appears but also an equation $i = i_0 \exp[(e\int_0^x (dv/dx)dx)/KT]$, which may be used to explain lack of saturation observed in thermionic currents as the applied PD is increased indefinitely. A discussion of the upper limit X of the integral appearing in this last equation follows and it appears that assuming sufficient experimental confirmation of the equation, a variable value of the dielectric constant is indicated in the work function region and this in turn implies that the electrons in this region are still in their atomic orbits.

SATURDAY AFTERNOON AT 2 O'CLOCK

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Room 401

24. Evidence for collisions of the second kind in the rare gases. GAYLORD P. HARNWELL, Princeton University.—A positive ray apparatus was used to investigate the products of ionization by electron impact in mixtures of helium, neon, and argon. The variation with pressure of the ratio of the two types of positive ions present was investigated in detail for three cases.

Case 1. A mixture of half helium and half neon was investigated. The ratio He/Ne was found to decrease regularly between .03 mm and .15 mm. At .03 mm the mean free path is approximately equal to the dimensions of the apparatus. Case 2. A mixture of half neon and half argon was investigated throughout the same pressure range. The ratio Ne/A decreased regularly between .05 mm and .15 mm, but this decrease was less rapid than in Case 1. Case 3. This mixture was half helium and half argon, and the pressure range was as above. The ratio He/A remained constant within experimental error, but as this mixture is least suited to analysis in a positive ray apparatus this result is the least conclusive. The observed effects are best explained by a type of collision of the second kind equivalent to ionization by positive ions. To account for the results obtained an electron must be transferred from an atom to an ion at a certain fraction of the collisions between an atom and an ion of lower ionizing potential.

25. Critical potentials of iron. RICHARD HAMER and S. SINGH, University of Pittsburgh.—The critical potentials of iron were investigated up to 132 volts. A long quartz tube enclosing two electrodes consisting of a central iron rod and a concentric iron cylinder was heated externally. Changes in potential could be made in practically equal or alternately large and small steps. Equal ones facilitated the plotting of differential curves. Alternate large and small steps facilitated observing differential deflections at desired potentials. Applied potentials were measured with a potentiometer. Repeatedly occurring breaks in the current potential curves were taken to indicate critical potentials. Many were checked by the differential methods. Those found are 3.7, 7.15, 11.2, 16.3, 19.4, 24.5, 29.0, 33.9, 38.8, 42.1, 45.7, 48.4, 51.4, 54.8, 61.6, 72.7, 89.6, 103.1, 111.6, 125.8 volts. Thomas and Compton did not find 38.8 and 45.7. Except 72.7 and 89.6, all check with the observations of Thomas, usually within 0.3 volt. No marked break was, however, observed by us at 82.7. Possibly our 89.6 is an average effect corresponding to his 82.7 and 94.8. The method is being developed to differentiate multiple and fine structure potentials.

26. The ionization in HCl vapor. HENRY A. BARTON, National Research Fellow, Harvard University.—A mass spectrograph was used to study ionization in HCl vapor at low pressures, the resolving power being sufficiently good to distinguish between $(HCl)^+$ and Cl^+ and to separate the isotopes. The results show that in pure HCl the primary type of ion formed by electron impact is $(HCl)^+$. This is true from the ionizing potential of 13.8 volts to at least 75 volts. Cl^- ions were likewise observed but chiefly from near the filament where no electrons of more than three or four volts energy were available. Probably the HCl was dissociated at the filament, the Cl atoms then picking up electrons by virtue of their electron affinity. Further evidence of such dissociation was furnished by the observation of H_2^+, H^+, and Cl^+ ions from impact. These ions were most prominent shortly after evacuation suggesting that water vapor from the walls aided in the dissociation. Detection of $(H_2O)^+$ ions then confirmed the presence of water vapor. After some days the only ions at low pressures were $(HCl)^+$ and Cl^-, the latter probably not from impact. Thus the results are contrary to the previously held assumption that H^+ and Cl^- are the products of electron impact in HCl.

27. Ultra-ionization potentials of mercury. ERNEST O. LAWRENCE, National Research Fellow, Yale University.—By a method of magnetic analysis of the bombarding electrons it has recently been shown that there are a succession of distinct types of inelastic impacts in mercury vapor above the ionization potential. (Phys. Rev. **28,** 947 (1926)). Earlier measurements of the ionization of mercury by electron streams possessing Maxwellian velocity distributions by many investigators failed to bring out these critical potentials, although it seems that they should have been observed in a qualitative manner. The apparent discrepancy has been eliminated for the present investigation has shown that the ultra-ionization potentials are observable when using Maxwellian velocity distributions in the electron streams providing sufficient care is taken to insure constancy of conditions and the ionization is observed at intervals of 0.1 volt.

28. Ionization of mercury vapor by λ2537. PAUL D. FOOTE, Bureau of Standards.—Measurements of the photoelectric effect in Hg vapor were made by the method employed for caesium vapor. (Phys. Rev. **27,** 37 (1926).) Although the data were confined to a vapor pressure range and ratios of amplified photo-current to initial thermionic current, which were less than the corresponding values in caesium at which occur departures from the linear relation between photo-current and illumination, the relation for Hg vapor between illumination I and photo-current Δi was of the form $\Delta i = AI^2/(1+BI)^2$ where A and B are constants for a given vapor pressure. This law holds accurately in the range investigated, 25° to 60°C. Admixture of nitrogen greatly increases the effect while small amounts of hydrogen reduce the current rapidly to zero, as has been found by Houtermans. The above law approaches the relation $\Delta i = AI^2$ for small intensities, as found by Rouse and Giddings, showing that two separate excited atoms (since only the core of λ2537 is effective) are involved in the ionization process. The increase by nitrogen shows that the metastable state 2^3P plays a role. Hydrogen at a pressure of 0.0002 mm reduces the current to half its initial value. Since the quenching of 2^3P_1 by hydrogen, as observed in resonance radiation, is inappreciable for such small pressures the concentration of the $^3P_0$ atoms exceeds by a large factor that of the $^3P_1$ atoms. The complete mechanism of the ionization process is considered in some detail.

29. The striated discharge in hydrogen and helium. JOHN ZELENY, Yale University.—The striated discharge between cold electrodes in hydrogen exhibits the remarkable property that the distance between the striae for constant current in the tube passes through a sharp minimum as the pressure is increased, and at a higher pressure passes through a maximum. The pressures at which these reversals occur and the magnitudes of the changes are dependent on the current through the tube and on some other factors. At pressures near that at which the minimum stria distance is observed, the Faraday dark space, which covers about 2 cm of length in most of the pressure region indicated, contracts and one or more striae leave the head of the positive column and move up to and surround the cathode. The stria distance in helium was measured between pressures of 2.7 and 9.7 mm, and for these two pressures was found to be 11.3 mm and 6.0 mm, respectively, with 6 m.a. current. Measurements made in argon, oxygen, and air under the same conditions are also given, but the range of pressures in which measurable striae were observed is much more limited.

30. Pressures in discharge tubes, Part 1,—Long slim tubes. W. H. CREW and E. O. HULBURT, Naval Research Laboratory, Washington, D. C.—The pressure changes in a discharge tube 3 m long, diameter 10 mm, due to uncondensed discharges were measured by a striation gauge. The striation gauge consisted of a second discharge tube (joined to the first) excited by direct current calibrated so that the shift of the striations of the positive column with pressure was known. With helium the temperature increment above the temperature, with no discharge, about 300°K, calculated from the pressures, were, respectively, 4°, 13° and 21°C for 200, 600 and 1000 watts in the long tube. With

wet hydrogen the pressure increments, corrected for temperature, gave for γ, the concentration of hydrogen atoms (i.e., the number of atoms divided by the number of atoms plus molecules) values which increased rapidly with the power to about 400 watts, being thereafter appreciably constant; the values of γ for 150 watts in the tube were about 10, 25, 50, 90 and 100 percent at pressures 0.4, 0.3, 0.2, 0.15, and 0.1 mm of Hg. With dry hydrogen and with oxygen γ was less, with nitrogen γ was close to zero. Complete curves were obtained with air, CO_2 and CO. Observations were also made with condensed discharges.

31. Movements of striae in discharge tubes under varying pressures. L. H. DAWSON, Naval Research Laboratory, Washington, D. C.—The striae of the positive column of a discharge tube move along the tube when the pressure of the gas in the tube is varied. The curves of this motion have been obtained as a function of the pressure, the distance apart of the electrodes, the diameter of the tube and the density of the current for wet and dry hydrogen, helium, nitrogen, air, carbon monoxide and carbon dioxide. The pressures, measured by a McLeod gauge, ranged from 0.6 to 0.05 mm of mercury. With these curves the discharge tube may be used as sensitive and quickly responding pressure gauge. The motion of the striations increased with the diameter of the tube being roughly ten times greater in tubes 30 mm in diameter than in tubes 16 mm in diameter. For tubes in which the distance between the electrodes was less than the maximum distance of motion of the striae, as the pressure was diminished the positive column marched into the anode without distortion and vanished.

32. The constancy of the flashing period of a neon glow-lamp. ELIAS KLEIN, Lehigh University.—The comparison of a neon-lamp frequency (operated on d.c.) with that of a standard clock is accomplished by a pendulum which cuts off a light-beam incident upon a photo-electric cell connected with the grid of a vacuum tube. The neon lamp is placed directly in the plate circuit, or in a separate circuit which is coupled to the plate circuit, of the vacuum tube. The period of the lamp is adjusted by capacitance and resistance associated with the lamp. Periodically, the pendulum admits light to the cell, the grid becomes negative and the space-current is reduced to zero thereby suppressing one or more lamp-flashes. While the cell is inoperative the lamp-frequency is again that which is characteristic of the circuit. Therefore, one pendulum cycle marks two clock-intervals during which the lamp completes a number of flashes. If the lamp-period is constant, each interval shows exactly the same number of flashes. Preliminary observations indicate the lamp-period constancy to a fair degree of precision. Replacing the pendulum by a tuning-fork-shutter yields similar results. This is also a method for subdividing intervals of time.

33. An absolute ionization vacuum gauge. THOMAS H. JOHNSON, Yale University.—The inconvenience of calibration has been eliminated in this new simply constructed gauge. The electrodes, which consist of a fine, straight incandescent filament between and parallel to two plane plates, are maintained at potentials which give a uniform electric field over the electron paths. The gauge constant, k, defined as the ratio of the pressure to the number of ions per electron, is obtained by means of the relation $k = V_+/(a\int_0^{V_+} P(v)\,dv)$ where a is the distance and V_+ the potential between the filament and the positive plate, and $P(v)$ is the ionization probability per centimeter at unit pressure expressed as a function of the electron energy. (See Compton and VanVoorhis, Phys. Rev. **27**, 724, (1926).) This method of obtaining the gauge constant assumes that all of the positive ions go to the negative plate. Ionization due to secondary electrons is neglected. Furthermore the effect of space charge on the electron paths and the potential distribution along the paths is not considered. However, measurements in mercury vapor in equilibrium with liquid mercury at 0°C, corrected for thermal effusion, show that the calculated constant is very nearly correct if V_+ is greater than 75 volts.

34. Post-arc conductivity and metastable states in mercury. M. L. Pool, University of Chicago (Introduced by A. J. Dempster).—For pressures from 0.3 to 10 mm current—potential curves have been obtained which suggest that around the collecting electrodes there exist negative and positive space charge sheaths. Residual positive ions may, depending upon the size of the collecting electrodes, be made to persist as long as 1/10 sec. Galvanometric current—low potential curves have been obtained which can be explained by the diffusion of electrons from a region of high electron and positive ion concentration near the cathode. Cathode ray oscillograph curves which show (even in the presence of air, He, H_2, CO_2, or A) a critical potential of about +3.2 volts can be accounted for by the same assumptions. No convincing evidence of a long lived (1/20 sec.) metastable state has been found. The apparent long lived states deduced from absorption of certain spectral lines may be due to the continuous formation of metastable states of very short life as the positive ions recombine. Impurities may thus have a large influence on these short lived atoms while not, however, altering the slow process of their formation.

35. Excitation of mercury vapor by positive ions. Ernest J. Jones, University of Minnesota.—Saturated mercury vapor at 90°C was bombarded with positive potassium ions from the source developed by Kunsman. The resulting radiation from a field free space was photographed by a quartz spectrograph. At 160 volts accelerating potential only the 2537 line appeared after six hours exposure, with an average ion current of 1.5×10^{-5} amperes. At 640 volts and four hours exposure with an ion current of 2×10^{-5} amperes the following lines were obtained; 2537 ($1S-2p_2$), 3126 ($2p_2-3d_2$), 3132 ($2p_2-3d_3$), 3650 ($2p_1-3d_1$), 4046 ($2p_3-2s$), 4358 ($2p_2-2s$). At 1200 volts and under the same conditions the above lines were again photographed. No new lines appeared. At the latter potential the intensity of lines originating from levels higher than the $2p_2$ was increased roughly 100% relative to that of the 2537 line. Comparison with the spectra excited by the electrons shows; (1) that the efficiency of excitation by positive ions is far less than by electrons; (2) that it increases with velocity at least up to 1200 volts; (3) that up to 1200 volts the probability of excitation to the $2p_2$ level is greater than to higher levels; (4) that up to 1200 volts the excitation to levels higher than the $3d_{1,2,3}$ is not observed with a four hour exposure and current of 2×10^{-5} amp.

SATURDAY AFTERNOON AT 2 O'CLOCK

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Room 428

36. Thermal conductivity of fused quartz as a function of temperature. Herman E. Seeman, Cornell University.—Preliminary measurements of the thermal conductivity of a specimen of clear fused quartz indicate that this property increases linearly with the temperature, within experimental error, from .0026 cal./cm. deg. sec. at −25°C to .0064 cal. /cm. deg.sec. at 950°C. The specimen was in the form of a hollow cylinder, closed at one end with a hemispherical cap. Energy to maintain a steady temperature gradient was supplied by means of an electrically heated filament mounted axially inside the specimen. Thermal contact with the specimen was made with mercury inside and outside at the lower temperatures and with the tin-lead eutectic at the higher, temperatures. Inside and outside temperatures were obtained with thermocouples. A guard ring scheme was used to prevent heat loss or gain at the open end of the cylinder and correction was made for the heat flow through the hemispherical end cap.

37. Thermal expansion of beryllium. Peter Hidnert and W. T. Sweeney, Bureau of Standards.—Data on the linear thermal expansion of beryllium between −120 and +700°C have recently been obtained. The rod investigated was prepared by the

Beryllium Corporation of America, and was found to have a density of 1.835 grams per cubic centimeter at 20°C. The coefficient of expansion increases rapidly with temperature. The coefficients or rates of expansion at -110 and $+650$°C are 5×10^{-6} and 20×10^{-6} respectively. Beryllium expands considerably less than the other elements of sub-group II B (Mg, Zn, Cd and Hg). Average coefficients of expansion for various temperature ranges are given in the following table.

Temperature Range: °C	Coefficient of Expansion $\times10^{-6}$	Temperature Range: °C	Coefficient of Expansion $\times10^{-6}$
-100 to -50	7.0	20 to 300	14.0
-120 " $+20$	8.1	20 " 400	14.8
-50 " 20	9.8	20 " 500	15.5
$+20$ " 100	12.3	20 " 600	16.1
20 " 200	13.3	20 " 700	16.8

38. On the calculation of changes of functions involving factorials as applied to entropy calculations. MORTON MASIUS, Worcester Polytechnic Institute.—In entropy calculations in connection with the kinetic theory of gases or the quantum theory the changes in functions depending on factorials have hitherto been calculated by a method depending on the replacement of factorials by continuous functions and differentiation. This method is neither simple nor logically satisfying. A new method of calculation is shown which depends on the direct evaluation, by simple well known processes, of

$$\Delta F = F(x+\Delta x,\ y+\Delta y,\ \cdots) - F(x,\ y,\ \cdots)$$

where F is a function involving the factorials of $x, y, \cdots$, and where $x, y, \cdots$ and $x+\Delta x, y+\Delta y, \cdots$ are taken as integers. The details of this method are illustrated by the treatment of two examples:

$$F_1 = \log\{[(n+p-1)!]/[(n-1)!\,p!]\}$$

and

$$F_2 = \log\{[n!]/[n_0!\,n_1!\,n_2!\cdots n_p!]\}$$

In F_1 the change in F_1 produced by some change Δp is found, and in F_2 the condition for making F_2 a maximum, subject to the additional restrictions that $\sum n_i = n$ and $\sum(in_i) = p$ is derived.

39. Properties of substances and mixtures in the condensed state at the absolute zero of temperature. R. D. KLEEMAN, Union College.—With the theoretical researches previously communicated to the Physical Society (Philadelphia meeting) as basis, a number of properties of a substance or mixture in the condensed state at the absolute zero of temperature have been deduced. The most important of these are: $c_v=0$, $(\delta c_v/\delta T)_v=0$, $(\delta^n c_v/\delta v^n)T=0$, $c_p=0$, $(\delta c_p/\delta T)_p=0$, $c=0$, $dc/dT=0$, $(\delta p/\delta T)_v=0$, $(\delta^2 p/\delta T^2)_v=0$, $dp/dT=0$, $d^2p/dT^2=0$, $(\delta v/\delta T)_p=0$, $(\delta^2 v/\delta T^2)_p=0$, $dv/dT=0$, $d^2v/dT^2=0$, where p denotes pressure, v volume, T absolute temperature, and c_v, c_p, c, the specific heats at constant volume, constant pressure, and under vapor pressure, respectively. The total differential coefficients refer to a substance or mixture under the pressure of its vapor. In the paper quoted it was shown directly that $c_v=0$, a result which is included in Nernst's Theorem. It is now shown that also $c_p=0$ and $c=0$, and that the specific heat possesses also the important properties expressed by $(\delta c_v/\delta T)_v=0$, $(\delta c_p/\delta T)_p=0$, and $dc/dT=0$.

40. On the surface heat of charging. LEWI TONKS and IRVING LANGMUIR, General Electric Co.—Two methods are available for calculating the theoretically necessary reversible heat development, or absorption accompanying the charging of the surface of a conductor. One method depends on a new relation $\eta_{S1}-\eta_{S2}=kT\ln(A_1/A_2)+\epsilon P_{21}$ between the surface heats, η_S of the two surfaces, the $A^1{}_S$ of electron emission equations of the type $i=AT^2e^{-b/T}$ and the Peltier heat at the interface between the conductors. The other method consists of a comparison of the cooling effect of electron emission and

the latent heat calculated from the temperature variation of emission. Experimental evidence points to $\eta_S = 0$ (nearly), $A = 60.2$ amps/cm^2 deg^2 (nearly) for all pure metals. Published cooling effect measurements on an oxide coated filament give $\eta_S = 0$ whereas the value of A gives η_S not equal to zero. This leads to no contradiction if only part of the surface is emitting electrons. For monatomic films cooling effect measurements are lacking but the values of A give both positive and negative surface heats of charging.

41. Thermal agitation in conductors. H. NYQUIST, American Telephone and Telegraph Company.—At the December, 1926, meeting of the American Physical Society, J. B. Johnson reported the discovery and measurement of an e.m.f. due to the thermal agitation in conductors. The present paper outlines a theoretical derivation of this effect. A non-dissipative transmission line is brought into thermodynamic equilibrium with conductors of a definite temperature. The line is then isolated and its energy investigated statistically. The resultant formula is $E_\nu^2 d\nu = 4kTRd\nu$ for the r.m.s. e.m.f. E_ν contributed in a frequency range one cycle wide by a network whose resistance component at the frequency ν is R. I and k are the absolute temperature and the Boltzmann constant. Experimental data are available for the audible range and there the agreement between the formula and the data is good. It will be observed that neither the charge nor mass nor any other property of the carrier of electricity enters the formula explicitly. They enter indirectly through R. The formula above is based on the equipartition law. If the quantum distribution law is used the expression becomes

$$[4h\nu R/(e^{h\nu/kT}-1)]d\nu.$$

The two expressions are indistinguishable in the range of the measurements.

42. Temperature variations in wires heated by alternating current. L. SMEDE, Westinghouse Elec. and Mfg. Co., East Pittsburgh.—Corbino, in 1910 and 1911, gave a solution of the problem of the temperature variation of a wire heated by alternating current. In this solution it is assumed that the temperature variation is small compared to the average temperature of the wire. Certain terms are neglected in order to simplify the solution, which seem too large to neglect. In the present paper it is assumed that, for small temperature variations, the radiation is proportional to the first power of the absolute temperature, and that the resistance remains constant. On these assumptions an equation is derived which gives the same temperature variation as derived by Carbino.

43. Internal friction in solids. A. L. KIMBALL and D. E. LOVELL, General Electric Co.—The internal friction of seventeen different solids is studied by a method previously described before this society (Phys. Rev. **25**, 899 (1925)). By this method it was found that in every case the dissipative forces were the same whatever the speed of deformation, contrary to the assumption of many investigators that the forces are greater the more rapid the deformation. A simple approximate law of internal friction in solids which in general best fits the facts is $F = \xi f_m^2$ where F = frictional loss per unit volume per cycle of stress at a point in the solid. f_m = maximum value of the stress amplitude at that point during a stress cycle. ξ = proportionality factor which may be called the internal friction constant. Values of ξ are tabulated for a number of different solids.

44. The nodal lines of bells. ARTHUR TABER JONES, Smith College.—Two systems of nodal lines are generally recognized for bells: A system of circles parallel to the mouth, and a system of vertical meridians. In the present work the number and position of these lines are checked for the lower modes of vibration and are determined for higher modes than those for which they have previously been known. The work was done as part of another investigation on the ten bells of the Harkness Memorial Chime at Yale University. The method was similar to that described in the Physical Review, **16**, 247 (1920). On all of the Harkness bells the first ten partials have respectively the following numbers of nodal meridians: 4, 4, 6, 6, 8, 8, 10, 8, 10, 12. The nodal circles are more

difficult to determine. For the first seven partials the numbers of nodal circles are: 0, 1, 0, 1, 1, 2, 2. The nodal circle for the second partial lies about 1/3 of the way up the bell, and for the fourth and fifth partials the corresponding fractions about 1/6 and 1/2. Surfaces of minimum intensity in the air close to the bells spread away from the metal in different directions for different partials.

45. Determination of the surface area of adsorbers. KART HOROVITZ, International Research Fellow, Rockefeller Institute.—It is known that certain fatty acids or their compounds form mono-molecular layers covering the available surfaces (Langmuir, Harkins, a.o.). Extensive experiments on surface tension of sodium oleate solutions under various conditions (DuNouy) lead to the conclusion that sodium oleate is also adsorbed in a mono-molecular layer at the interface of two phases. Assuming that this mono-molecular layer of sodium oleate is formed on every adsorber it is possible in an exceedingly simple manner to determine the surface area of the adsorber from the quantity of sodium oleate adsorbed and the known dimensions of the sodium oleate molecule. The adsorption of the sodium oleate was determined from the change in the static values for the surface tension of the sodium oleate solutions at different concentrations, using the ring method (DuNouy tensiometer). The surface of different charcoals determined by this method was found to be of the order of magnitude of some 100 sq. m. g charcoal, the ratio of the surface areas for charcoals of different origins being in good agreement with the determination by other methods and other investigators.

SUPPLEMENTARY PROGRAM

46. Inelastic collisions in ionized gas mixtures. GAYLORD P. HARNWELL, Princeton University.—The variation with pressure of the ionization by electron impact in mixtures of the rare gases with hydrogen and nitrogen was studied using a positive ray apparatus. All the results described refer to mixtures of the gases concerned in equal proportions. Mixtures of hydrogen with helium, neon, and argon were investigated in turn. In each case the number of rare gas ions decreased rapidly after a pressure of about .05 mm was reached. At this pressure the mean free path was approximately equal to the dimensions of the apparatus. H_2 decreased slightly with pressure but less rapidly than when the rare gas was not present. H_1 and H_3 increased, the latter very rapidly except in the case of the neon mixture where the increase was less marked. In mixtures of nitrogen and the rare gases the same type of effect was observed. At higher pressures the rare gas ions decreased at approximately the same rate as the N_2 ions. The N_1 ions increased, being present in slightly greater numbers when the rare gases were present than when they were not. These results definitely support the other evidence for the existence of a type of collision of the second kind resulting in ionizations by positive ions.